The newsletter of NASA's Discovery and New Frontiers Programs of missions exploring our solar system

Discovery AND New Frontiers NEWS

GRAIL's Ebb and Flow Hard at Work

The twin lunar Gravity Recovery and Interior Laboratory (GRAIL) spacecraft lifted off from Cape Canaveral Air Force Station in Florida on September 10, 2011, to study the Moon in unprecedented detail. Flying in tandem orbits around the Moon, the twin solar-powered spacecraft will measure the lunar gravity field to provide answers to long-standing questions about our closest neighbor in the sky and give scientists a better understanding of how Earth and other rocky planets in the solar system formed.

GRAIL took a mellow, low-energy trajectory to the Moon, traveling more than 2.5 million miles in nearly four months, which allowed time for spacecraft checkout and final planning for lunar operations. On December 31, GRAIL-A (renamed Ebb, see below) celebrated New Year's Eve by entering lunar orbit at about 6 pm ET. GRAIL-B (renamed Flow) followed suit on New Year's Day, achieving orbit at about 5:43 pm ET on January 1. The insertion maneuvers placed the spacecraft into a near-polar, elliptical orbit with an orbital period of approximately 11.5 hours. Since then, the GRAIL team has executed a series of burns with each spacecraft to reduce their orbital period to just under two hours.

On March 6, the two GRAIL spacecraft officially began their science collection phase. During this phase, the spacecraft will transmit radio signals precisely defining the rate of change of distance between the two. The distance between the spacecraft will change slightly as they fly over areas of greater and lesser gravity caused both by visible features such as mountains and craters and unseen masses hidden beneath the lunar surface.

The spacecraft are in a near-polar, near-circular orbit. They will circle the Moon from as high as 31 miles and as low as 10 miles, getting as close to each other as 40 miles and as far apart as 140 miles, returning data to allow scientists to create a high-resolution map of the lunar gravitational field that will tell us about the Moon's internal structure and composition in unprecedented detail.

Originally planned for an 84-day science phase ending on May 29, NASA has announced it will extend the mission through December 31. During the extended mission, GRAIL will fly at a lower altitude that will improve spatial resolution and offer more detailed gravity mapping. This will provide a better understanding of density variations within the highland crust and maria, both horizontally and with depth. Scientists will be able to map structures beneath geological features, something that has not been done before.

The United Launch Alliance Delta II rocket carrying the GRAIL spacecraft lifts off from Space Launch Complex 17B. Credit: Photo by Thom Baur, United Launch Alliance

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Montana Students Name GRAIL Twins, Ebb and Flow

The names Ebb and Flow replaced GRAIL-A and -B, thanks to fourth-grade students from the Emily Dickinson Elementary School in Bozeman, Montana. A nationwide student contest kicked off in October to choose names for the two spacecraft. Nearly 900 classrooms with more than 11,000 students from 45 states, Puerto Rico, and the District of Columbia participated in the competition, with teachers submitting short essays for their class's entry.

On January 17, NASA announced the winning names, "Ebb and Flow," submitted by Nina DiMauro's 28 fourth graders. "The class really hit the nail on the head," said GRAIL Principal Investigator Maria Zuber from the Massachusetts Institute of Technology. "We were very impressed that the students drew their inspiration by researching GRAIL and its goal of measuring gravity. Ebb and Flow truly capture the spirit and excitement of our mission."

Fourth graders from Emily Dickinson Elementary School who chose the winning names.

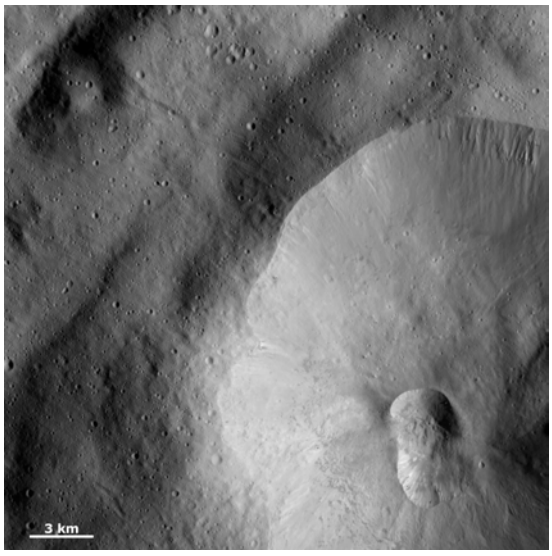
The winning prize for the students is to choose the first images from the MoonKAM. See one of their selected images (below). Dickinson is one of more than 2,500 schools registered for the MoonKAM program that began on March 12. Teachers can still register for the free program.

Each spacecraft carries a small camera to engage middle schools across the country in the GRAIL mission and lunar exploration. Thousands of fifth- to eighth-grade students will select target areas on the lunar surface and send requests to the GRAIL MoonKAM Mission Operations Center. Photos of the target areas will be sent back by the GRAIL satellites for students to study. The MoonKAM program is led by Sally Ride, America's first woman in space, and her team at Sally Ride Science in collaboration with undergraduate students at the University of California in San Diego.

This image of the lunar surface on the Moon's far side was taken by the MoonKAM system on the Ebb spacecraft on March 15, 2012. It's among the first set of student-requested pictures, featuring the 42-mile-wide Poinsot crater in the middle of the image. Credit: NASA/Caltech-JPL/MIT/SRS

Dawn Reveals Vesta's Impressive Features

Since entering into orbit around the giant asteroid Vesta last August 11, the Dawn spacecraft has transformed perceptions about this mysterious world as it returns incredible close-up images, including one that features a mountain three times as high as Mount Everest. The new views of Vesta are adding to the body of knowledge about processes of early solar system formation.



The double crater in this image from Vesta's south pole region was likely formed by the simultaneous impact of two fragments of a split projectile. The area outside the larger crater features a high density of smaller craters in clusters or chains. Gullies are visible along the top rim of the crater. Image credit: NASA/ JPL-Caltech/ UCLA/ MPS/ DLR/ IDA

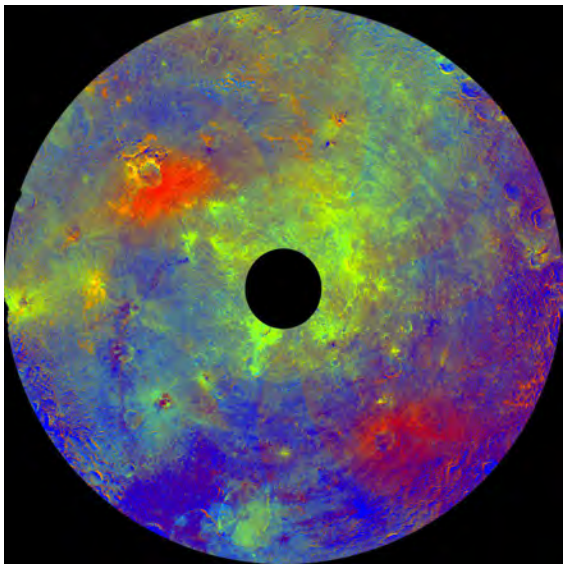
In September the spacecraft spiraled to its High Altitude Mapping Orbit, or HAMO, where it spent 30 days collecting photos and data from an average distance of 420 miles above the surface. Viewing the asteroid both straight down and from multiple angles, the images are being used to create topographic maps that reveal the heights of mountains, the depths of craters, and the slopes of plains, helping scientists understand the geological processes that shaped Vesta.

Scientists have discovered that Vesta's surface, viewed by Dawn at different wavelengths, has striking diversity in its composition, particularly around craters. The surface appears to be much rougher than most objects in the main asteroid belt. A method for age dating that uses the number of craters indicates that areas in the southern hemisphere are 1 billion to 2 billion years old, much younger than areas in the north.

Colorized images of Vesta show different rock or mineral types, revealing Vesta to be a world of many varied, well-separated layers and ingredients. Vesta is unique among asteroids visited by spacecraft to date in having such wide variation, supporting the notion that it is transitional between the terrestrial planets and other asteroids.

In December, Dawn maneuvered into its closest orbit around Vesta to begin a new phase of science observations, the Low Altitude Mapping Orbit, or LAMO, which circles the asteroid at an average altitude of about 130 miles above the surface. The primary science objectives in this orbit are to learn about the elemental composition

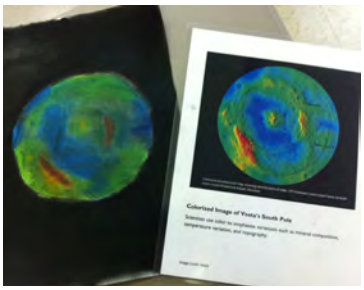
This image from Dawn's framing camera shows Vesta's southern hemisphere, centered on the Rheasilvia impact basin, which is about 290 miles in diameter with a central mound reaching about 14 miles high. The colors are assigned by scientists to show different rock and mineral types.



of Vesta's surface with the gamma ray and neutron detector and to probe the interior structure of the asteroid by measuring the gravity field. Images from low-altitude mapping orbit show great details, including abundant small craters, small grooves, and small outcrops of bright and dark material.

Education and Public Outreach Highlights

Dawn's E/PO team has created interactives to explain how the mission's three instruments work. The newest one, the Framing Camera Interactive, explains how the camera's black and white images are interpreted with color filters to help scientists, and all of us, make sense of them.



Fifth-grade student's interpretation of Vesta.

Dawn participated in two recent Discovery/New Frontiers Program collaborative efforts. First, in November Dawn helped bring NASA Week to 1,200 students in grades 4–12 at Plainview School in Rainsville, Alabama. The classroom sessions and educator workshop brought rich STEAM (science, technology, engineering, arts, math) experiences to support teachers and students, whose school was heavily damaged during last spring's severe tornado.

Among other activities, kids created their own renditions of asteroid images, explored the scale of space with "Where Are You?" and interacted with Dawn's Ion Propulsion activities.

Dawn also played a key role in the March educator workshop, "A Vision of Discovery," with mission scientists presenting the latest findings and two activities using art to inspire science learning (see page 7 for more information).

NASA Extends MESSENGER Mission

In November, NASA announced extension of the MESSENGER mission for an additional year of orbital operations at Mercury. On March 18, 2011, MESSENGER became the first spacecraft to orbit the innermost planet and capture the first global close-up images of it. On March 17, 2012, MESSENGER successfully wrapped up its first year in orbit, and the following day it began the extended phase designed to build upon the discoveries made so far, which are revolutionizing scientific perceptions of the planet.

MESSENGER has captured nearly 100,000 images and returned data that have revealed new information about the planet, including its topography, the structure of its core, and areas of permanent shadow at the poles. The September 30 issue of *Science* had seven reports with new details about Mercury's surface composition, geologic history, and magnetic field. The latest findings are presented in two papers published online in the March 21 issue of *Science Express* and in 57 papers presented at the 43rd Lunar and Planetary Science Conference.

"The first year of MESSENGER orbital observations has revealed many surprises," said MESSENGER Principal Investigator Sean Solomon, of the Carnegie Institution of Washington. "From Mercury's extraordinarily dynamic magnetosphere and exosphere to the unexpectedly volatile-rich composition of its surface and interior, our inner planetary neighbor is now seen to be very different from what we imagined just a few years ago."

This image of Mercury's Hodgkins Crater displays the beautiful interior and ejecta blanket of a fresh, rayed impact crater. Up close you can see that Hodgkins formed partially atop an older crater and has a small rayed crater on its ejecta blanket. Credit: NASA/JHUAPL/CIW

Findings from the first six months in orbit include:

- Previously unknown hollows dot Mercury's surface. The depressions may have formed when volatile compounds suddenly sublimated into gas. That could mean the planet contains more easily vaporized elements than scientists had predicted.
- Smooth, volcanic plains stretch over a large region near Mercury's north pole. Lava flows cover more than 40 percent of the planet, indicating extensive and relatively recent volcanism.
- Mercury's surface composition is different from that of the other rocky planets, with 10 times as much sulfur as Earth's crust. The odd composition means that scientists will have to rethink their models of how Mercury formed.

- The planet's magnetic field is strangely uneven, especially relative to its size. Scientists cannot yet explain the asymmetry, but doing so should help them understand what is churning in Mercury's dense, iron-rich interior.

The extended mission will allow scientists to learn even more, with a greater amount of time spent at low altitude, a broader range of scientific objectives, and more targeted observations than during the primary mission. MESSENGER will also capture Mercury's response to changes in its environment as solar activity continues to increase toward the next maximum in the solar cycle, which is expected to yield new surprises.

The extended mission is designed to answer six scientific questions raised by discoveries made from orbit:

1. What are the sources of surface volatiles on Mercury?

2. How late into Mercury's history did volcanism persist?

3. How did Mercury's long-wavelength topography change with time?

4. What is the origin of localized regions of enhanced exospheric density at Mercury?

5. How does the solar cycle affect Mercury's exosphere and volatile transport?

6. What is the origin of Mercury's energetic electrons?

MESSENGER Captures the Public's Imagination

Discover magazine named the MESSENGER mission one of the top 100 stories of 2011. "These stories capture scientific curiosity in all its stages: provocative early results, long-sought confirmation, and many steps in the iterative process of testing theory against observation and vice versa," wrote *Discover* Editor-in-Chief Corey Powell. MESSENGER came in at 25 among the 100.

Education and Public Outreach Highlights

MESSENGER educators and scientists have been sharing the science findings and images at a wide variety of gatherings, including a workshop for museum educators at the Goddard Space Flight Center, family science night at the Owen Science Center, Spacefest at the American Museum of Natural History, and family science night at the National Air and Space Museum.

Listen to updates on MESSENGER at both the 365 Days of Astronomy and Science Update websites. Search for "MESSENGER" to find podcasts. And tour Mercury with Google Earth, Explore Mercury. Mission scientists will be your guides as they explain their latest discoveries.

MESSENGER partnered with the Discovery Program and the New Horizons and Dawn missions to organize a thematic educator workshop, "A Vision of Discovery," attended by more than 120 at four locations across the country on March 10. The workshop focused on the using the elements of art to engage students in the appreciation and interpretation of NASA imagery. Mission scientists presented updates and education team members demonstrated new educational activities (see page 7 for more details and photos).

New Horizons Sets its Sights on Pluto

The distance that New Horizons covers on the way to Pluto is staggering — nearly a million miles every day. Currently more than 2.1 billion miles from Earth as it races outbound at 34,000 miles per hour, this amazing spacecraft has now covered two-thirds of its very long journey to the outer reaches of our solar system.

Few spacecraft travel 10 astronomical units during their entire mission. (An astronomical unit is the average distance between Earth and the Sun, about 93 million miles.) New Horizons has already logged more than twice that distance on its way to Pluto, reaching to within 10 AU of its main target in February. Six years since launch and with three years to go, it's fascinating to imagine the piano-sized probe speeding through the vastness of space, oblivious to its surroundings as it hibernates much of the time. The hardy craft continues to respond well to the periodic wake-up calls from the mission operations team at the Applied Physics Laboratory in Laurel, MD, to announce another round of systems and instrument check-outs.

Presenters and attendees at the New Horizons Pluto Encounter Hazards Workshop in November.

The last wake-up session in January was a month-long event. The next one will be an intensive two-month-long detailed check-out during May and June, highlighted by the first in-flight encounter rehearsal. New Horizons will perform every maneuver, every scan, and every observation that it actually will do around the closest approach in 2015. After the rehearsal, recorded engineering and science data will be played back to Earth and used to search for any discrepancies.

In addition, every system and its backup will be checked out, including each of the seven scientific instruments. The team will collect more science data than in any previous wakeup, update the command and control software, and more — all in preparation for a complete, nine-day encounter rehearsal in 2013. With only one shot at a close encounter with the Pluto system, the team is doing everything it can to assure getting the most science from its very fast flyby. The data New Horizons sends back — maps, spectra, plasma data, radio science, and more — will revolutionize our knowledge of the Pluto system and make every current book about it obsolete.

Education and Public Outreach Highlights

In February, the New Horizons E/PO team partnered with the Maryland Science Center in Baltimore to conduct an educator workshop on "Pluto and the Outer Solar System" with displays, demonstrations of classroom activities, speakers from the mission, and a Science on a Sphere program about the solar system.

New Horizons also participated in "Girl Power: Reach for the Sky," a STEM event held in March at the Applied Physics Lab for middle and high school girls to learn about career opportunities, participate in hands-on activities, and meet and talk with professional women in a variety of STEM careers.

Girl Power event at the Applied Physics Lab.

Would you like to get involved with the New Horizons mission? You can be an IceHunter, helping to identify a Kuiper Belt Object, or KBO, that the spacecraft could encounter after it passes by Pluto and its moons.

To find these icy KBO targets, the mission needs help to pore over thousands of ground-based images, taken specially for this purpose using giant telescopes. Hidden within the images are undiscovered slow-moving KBOS, asteroids zipping through the foreground, and millions of background stars.

The KBO target will not be selected until shortly before the Pluto encounter, but scientists hope to find one or more that the spacecraft can reach that are at least 30 miles across. The spacecraft would map the KBO with high-resolution images, investigate its composition using infrared spectroscopy and four-color maps, and look for an atmosphere and moons. Sound intriguing? Join the search!

Juno on Track for Jupiter

Nearly eight months after a spectacular launch aboard an Atlas rocket, the Juno spacecraft has traveled about 327 million miles so far, racing to Jupiter at a velocity of approximately 43,000 miles per hour. It will reach the massive gas giant planet in July 2016 and perform 33 orbits over 12 months, collecting data from its eight science instruments and capturing fabulous images from the JunoCam.

As the largest planet orbiting the Sun, Jupiter has had a profound influence on the solar system, but its origins remain a huge mystery. To learn how Jupiter formed and evolved, Juno will study its gravitation and magnetic fields and explore the swirling clouds that form Jupiter's colorful atmosphere. The spacecraft will reveal what Jupiter is made of, including how much of it is water.

Juno in orbit above Jupiter's colorful clouds, in this artist's rendering.

The Juno spacecraft is in excellent health. Four instruments are turned on: the magnetometer experiment, which consists of the flux gate magnetometer/advanced stellar compass; the Jupiter Energetic-particle Detector Instrument (or JEDI); the microwave radiometer; and the plasma waves instrument.

The Juno mission operations team is currently performing instrument compatibility tests. During these tests, each of Juno's science instruments is checked in turn to determine if its activity causes electromagnetic interference for any of the other instruments.

In October 2013, Juno will swing back around Earth for a gravity assist that will help propel it toward Jupiter. The flyby of Earth will also give engineers an opportunity to test the instruments and rehearse some of the operations that will take place at Jupiter.

Education and Public Outreach

You can travel to Jupiter alongside Juno with NASA's Eyes on the Solar System 3D interactive. If you're new to "Eyes on the Solar System," go here for an introduction and tutorials.

Kids can play the "JunoQuest" game and pretend they are in orbit around the gas giant planet, just as Juno will be.

OSIRIS-REx Efforts Underway

OSIRIS-REx, the first American mission designed to return samples from an asteroid, was selected as the third investigation in NASA's New Frontiers Program last May. The spacecraft will travel to a near-Earth carbonaceous asteroid, (101955) 1999 RQ36, study it in detail, and bring back a sample (at least 60 grams or 2.1 ounces) to Earth.

Since the selection was announced, the team has been extremely busy working on the many details that are part of starting a new mission, including filling staff positions, developing schedules, drafting required documentation, initiating contracts and procurements, and conducting reviews. The first science team meeting was held at the end of October, with the next one planned for April.

Sixty team members gathered in Denver during the last week of February for a "Design Reference Mission Walk-through" to discuss the details of just how the mission will operate. Participants discussed how all the flight maneuvers will enable the instruments to focus in on the asteroid to map its composition and topography, measure the orbital deviations, select a sample site, grab the sample, and return it to Earth.

The OSIRIS-REx mission is now in Phase B, the definition phase, during which the team plans exactly how the mission will succeed in meeting all its objectives. The instrument teams are working

on the detailed engineering of the instruments, defining how their instruments will operate and deal with unexpected discoveries at the asteroid.

The interplay of instrument needs and spacecraft capabilities and needs is quite complicated and a true balancing act. For example, aspects such as the amount of light, which are important for observations, can also affect navigation because light pressure can alter the orbit while too much light can put more heat stress on the spacecraft. The team will continue to bounce needs and solutions off one another until the mission is honed to the finest details, leading to the Preliminary Design Review in March 2013 and the Critical Design Review in May 2014.

Team members at the February meeting working on designing the details of the mission.

Sadly, the mission's principal investigator, Dr. Michael Drake, director of the Lunar and Planetary Lab at the University of Arizona, passed away in September. Drake was a highly respected scholar, administrator, and world-class scientist. During his long career at LPL, he studied the Moon, meteorites, Mars, and Earth. For the past seven years he was committed to making the OSIRIS-REx mission a reality. With colleague Dante Lauretta, he established an international team composed of multiple generations, and he was there leading the celebrations when NASA awarded the mission in May 2011. On that day, an elated Drake said the mission's scope is about "nothing less than the origin and destiny of humanity: Where did the organics come from that led to us? Will we go the way of the dinosaurs?" The team carries Michael Drake in their hearts as the mission goes forward, with Lauretta taking over as principal investigator.

Education and Public Outreach

The mission Education and Public Outreach has a variety of events planned for 2012. The first was the release of the mission's website in January.

In the late spring, *Target Asteroids!,* an observing program for citizen scientists, will begin. Amateur observers will take data on asteroids that may serve as targets for future missions and provide data that will enhance the understanding of 1999 RQ36.

In fall 2012, the OSIRIS-REx mission and The Planetary Society will hold the *Name that Asteroid!* contest to choose a snazzier name for (101955) 1999 RQ36.

Strofio Assembly and Test Continues

The Strofio team continues work on fabrication, assembly, and test of the instrument components. Strofio is a unique mass spectrometer that is part of the SERENA suite of instruments that will fly on board the European Space Agency's BepiColombo/Mercury Planetary Orbiter (MPO) spacecraft. Strofio will determine the chemical composition of Mercury's surface, providing a powerful tool to study the planet's geological history.

Strofio is funded by NASA as a Discovery Mission of Opportunity, which gives U.S. scientists the opportunity to fly instruments on foreign space missions.

The SERENA instruments include two Neutral Particle Analyzers (Strofio and ELENA) and two Ion Spectrometers (MIPA and PICAM). Together they will investigate the complex particle environment that surrounds Mercury called the "exosphere." The exosphere is different from an atmosphere. In an atmosphere, the molecules constantly collide and change their velocity. In the collision-free exosphere, the particles move due to gravity and, if present, sunlight pressure. Particles escape from Mercury's surface and flow out into the exosphere, then either return to the surface or are lost in planetary space.

The Structural and Thermal Model of the BepiColombo Mercury Planetary Orbiter in the Large Space Simulator at ESA's Test Centre in the Netherlands during preparation for thermal balance testing.

BepiColombo is a European Space Agency mission, in cooperation with Japan, to explore Mercury. The objectives are to:

- Investigate the origin and evolution of a planet close to the parent star
- Study Mercury's form, interior structure, geology, composition, and craters
- Examine the composition and dynamics of Mercury's exosphere
- Learn about the structure and dynamics of Mercury's magnetosphere
- Determine the origin of Mercury's magnetic field
- Investigate the composition and origin of polar deposits
- Perform a test of Einstein's theory of general relativity

The current plan is to conduct part one of a Strofio pre-ship review in June, with shipment of the proto-flight model to the University of Bern shortly thereafter. The flight unit is scheduled for completion in August, with the Strofio instrument planned for delivery to Italy in October for integration into the SERENA instrument suite. Launch of BepiColombo is now set for August 2015, with arrival at Mercury in 2022.

"A Vision of Discovery" Delivers Mission Science Artfully

On March 10, 120 educators gathered at four sites around the U.S. to experience A Vision of Discovery — Science Inspiring Art. A collaboration of the Discovery and New Frontiers Programs with the Dawn, MESSENGER, and New Horizons missions, the workshop featured scientists Ralph McNutt, Bonnie Buratti, and Nancy Chabot presenting the latest updates from the three missions and amazing images from asteroid Vesta and Mercury. All presentations can viewed on the webinar archive page.

Planetary artist and educator Monica Aiello led a captivating session on using elements of art to engage students in analyzing and understanding beautiful NASA images of space, called "Art and the Cosmic Connection." She explained how line, shape, color, value, and texture can help students interpret geological features on the rocky planets, moons, asteroids, and comets when they are taught to look for distinct features and draw them.

"I thoroughly enjoyed Saturday's workshop. Not only was it fun, but I came away with valuable lessons and resources that I will be sharing with my middle school colleagues. Thank you!"

"I've shared the materials with the 8th grade science teachers and our art teacher. I showed my principal what we did, and we're talking about doing the art activities during our next Professional Development day. I'm going to use my picture in our annual Arts Extravaganza in May, along with the laminated original. Thanks again!"

Dawn mission educators demonstrated another art activity that uses lightness and darkness, value or albedo, to help students analyze images. A MESSENGER Educator Fellow at each location led the Mosaic Postcards from Mercury activity.

The workshop was a follow-on to last year's successful "Thrill of Discovery" event. The sessions took place at the Jet Propulsion Laboratory, Pasadena; Johnson Space Center, Houston; Applied Physics Lab, Laurel, MD; and Oregon Museum of Science and Industry, Portland, with 245 watching the webinar in real-time on the Internet. Organizers included Shari Asplund, Whitney Cobb, Julie Edmonds, Heather Weir, Kay Tobola, and Jim Todd. Stay tuned for next year — we've got ideas for another great session.

NASA Brings Space to San Diego

The Discovery and New Frontiers missions and JPL colleagues brought a great NASA experience to thousands of kids and their families at the San Diego Festival of Science and Engineering's Expo Day at Petco Park on March 24.

Expo Day is the culmination of a week-long series of events to engage kids in science and engineering, raise awareness of the importance of STEM education, and inspire students to realize they have the potential to become tomorrow's scientists and innovators.

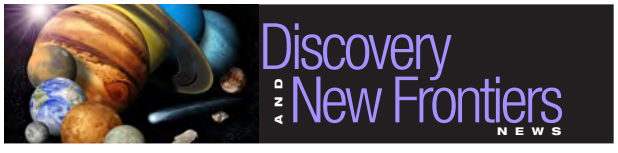
More than 27,000 area residents attended the all-day event, where the NASA–JPL booth featured Dawn and Discovery's other small bodies missions with size and scale, cratering, and comet-making activities. Kepler showed how the spacecraft detects planets with light curves, while one of Juno's education partners, the GAVRT program, had students operate a radio telescope from a computer, just as they would in the classroom. Mars brought models of rovers and a large 3D mural of the McMurdo panorama. MESSENGER displayed images of Mercury from their Mosaic Postcard activity. Solar telescopes engaged people of all ages in viewing the Sun.

On the Expo Day stage, 60 students from the Santee School District Out-of-School Time Programs and Boys and Girls Clubs of East San Diego County put on an out-of-this world performance of D/NF's "Space School Musical." With rehearsal assistance from the musical's creator, Kellee McQuinn of KidTribe, the students added their own creative touches and had loads of fun while they learned about space. The teachers said the outcome is priceless!

Space School Musical performed at Expo Day by students from Santee area after-school programs.

NASA at San Diego's Festival of Science and Engineering Expo Day, March 24, 2012.

Winner of a 2011 Society for Technical Communication International Summit Award of Excellence



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